PHENOLOGICAL RESEARCH IN GREENLAND
1964-1970

Final Technical Report

By

Ingolf Sestoft

- MAY 1970 -

EUROPEAN RESEARCH OFFICE

United States Army

Contract Number DA-91-591-EUC-3341

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ACKNOWLEDGMENT

In this difficult, but also very attractive research, skill and experience from different sciences meet: meteorology in general and climatology in particular, botany, forestry, genetics, ecology and topography (in relation to topo-climatology); further: economics concerning sheep farming &c as a form of agricultural farming.

Here Danish-Greenland national interests have met with American scientific sense and financial generosity. Thus I finally have the agreeable duty to direct my best thanks for good and useful collaboration, kindness and benevolence not only to the Danish cooperators already mentioned, be it inside or outside the Danish Phenological Committee, but not less to all the American officers and scientific experts, whose acquaintance I have had the pleasure to make, and from whom, through inspiring conversation, I have learned a lot.

I direct my most sincere thanks to them all - particularly the European Research Office as a whole, for all kinds of assistance, encouragement, good advice, indulgence and generosity.

Without the insight, knowledge and auxiliary power I thus met with, the realization of the whole project might hardly have been the same.

Ingolf Sestoft
Contractor
principal investigator.

Copenhagen, 20. April 1970.

CONTENTS

SUMMARY

Encouraged by new, promising results, gained through some years of phenological investigations on woody clone-plants, a group of Danish experts agreed in 1960 to attempt an extension of the phenological network in Europe by establishing a similar girdle of stations in Southern Greenland.

The purpose should be, as with phenology elsewhere, to find relationship between plant growth, foliation &c with climatic factors in order to use the plants as "living witnesses" about climatic development or seasonal, even secular changes, but also to utilize the data collected as supplements to ordinary climatological observations in desolate and remote regions.

The selection of plants, of course, would differ from those chosen for the European belt, but clone-plants should be used exclusively in order to secure comparable plants, biologically identic, also at the stations in Greenland.

Contact was taken and cooperation established with the European Research Office in Frankfurt a/M in 1963, and in April 1964 the first clone-plants were sent to Greenland. In 1965 the planned 6 stations were augmented to 10, arranged in 4 chains, each of them embracing 1 atlantic and 1-2 more or less continental station, viz. 3 stations in the two [redacted] chains and into the great fjords in the middle, and 2 in the boundary chains.

In 1966 the planting out at all 10 stations was achieved, and in spite of quite extraordinary, most unfavorable conditions as to climate and the polar drift-ice, preliminary results have been gained, allowing some considerations as to the relationship between phenological plant development and the relevant climatic factors in Greenland.

Ingolf Sestoft
principal investigator
1963-1970.

Introduction:

Phenology - pure and applied science

Phenology may, as a partly pure and partly applied science, be considered as a special branch of bioclimatology and may promote knowledge in varied fields, otherwise difficult to attain, be it from remote times or distant regions. For example the fruits of the date palm do not ripen at an annual mean temperature below 21°C, and vine grapes hardly above 22°C; hence the thermo-climatic values for these thus may be established with a considerable degree of accuracy for certain Southern and Eastern Mediterranean coastlands far back in antiquity. The study of old annual tree-rings may contribute to knowledge of climatic changes, especially of the moisture factor in geologic times.

Fundamental here is the quite plausible and empirically well supported assumption, that trees, shrubs and smaller plants will always keep their ecological, biological and bioclimatological properties as far as concerns the species belonging to the same clones or strains, thus being biologically identical.

The same assumption of biological clone-identity also constitutes a commom base of the phenological research in Southern Greenland, dealt with in this paper. As a method of producing an ample reproducing of such plants, totally akin, grafting or cutting is used systematically and exclusively. In Denmark this task is carried out at the Arboretum, Hoersholm, as well for the homeland as for the Greenland network of stations.

Phenology renewed in Denmark

Already in 1947 Dr. Syrach-Larsen as Director of the Arboretum had pointed out, that clonal trees may be utilized as "living meteorological stations'. Independently of this a similar conception was made by the present writer as well as by others elsewhere in Europe.

At the CAgM - I (first session of WMO's international Comission for Agricultural Meteorology), held in Paris in the late autumn of 1953 phenological research was an item of discussion. Since there was among the delegates from NW-Europe a feeling of the need for closer discussion and collaboration, Denmark arranged an unofficial meeting between these countries interested.

The next year, 1954, WMO approved the resolutions as to phenology of CAgM - I, and at a summermeeting (8. June 1955) at our Meteorological Institute, Charlottenlund, a Danish Phenological Committee was established, providing collaboration between the Institute, the Arboretum (at Hoersholm) and its mother-institution: The Royal Veterinary & Agricultural University.

Only some years later it was agreed to lend practical support to an European project, advanced by Germany (F. Schnelle & al.), in order to create a vast international chain of phenological gardens, reaching from the Mediterranean over Central Europe and Denmark to Northern Scandinavia.

Denmarks contribution to this great network was fixed at 3 - called: international - out of 10 phenological gardens, which were then established by collaboration between the Arboretum and Meteorological Institute (the writer). The achievements were discussed on an European level at a meeting on agro-meteorology in Wageningen, the Netherlands, in the autumn of 1955.

It was agreed, that phenological stations, now and later, should on the whole be pheno-climatological, errenged if possible at the State's experimental farms, in a number about twenty spread over the country, most of them in Jutland. Clonal plants from Arboretum should be used exclusively, viz:

oak : 3; ash : 3; beech : 6 (early 2, middle 2, late 2); larch : 3; spruce : 3; i.e. altogether 18 trees at each station. In order to secure equality in exposure to sunshine and wind, the trees were to be planted in triangles, making two long rows.

In a country such as Denmark this choice of trees was considered sufficient, the climatic variations running smooth. Later on as the number of pheno-climatological gardens was enlarged 2 or 3 times, even a still more restricted planting programme was adopted (secondary pheno- climatological gardens).

The purpose was, through regular observations, to:

1) compare the ecological effects of local particularities of climate on seasonal biological development (leafing-out, flowering, fruiting);
2) compare the changing climatic influences from year to year;
3) and, if possible, inversely: to estimate the changes of climatic factors from year to year - a valuable procedure for distant regions, without regular observations, not even automatic.

The most important climatic factors are: temperature, cloudiness/sunshine, moisture/precipitation and wind. With these, correlations may be built up.

Meteorological observations are generally taken 3-8 times a day, but phenological data: 3-4 times weekly ordinarily suffice. Yet, as supplements, photographs, close on buds &c, taken at fixed days of the months (1., 6., 11. or so) have been arranged, especially in April-May.

In fact, older phenological observations have been made in Denmark and elsewhere, but without strict observational regulations and with no use of clonal plants.

Replantings, of course, have been necessary in some cases of damage by frost and dryness, mostly in Jutland. And it will be so in the future also, when the trees grow so big as to "change" the local climate to which they should bear living witness.

Ingolf Sestoft

Planning of phenological gardens in Greenland

As this phenological research in the homeland had developed for some years, observations being gathered, stations inspected and some experience gained, the idea arose to extend the research to Greenland, where it might be of special value.

Meantime, already in 1960, leading officers in the Danish Defence Research Board had a similar conception, and contact was made with our committee in 1963, considering Southern Greenland or more specifically: the Julianehaab district apt for the purpose, because there phenology might be of distinct practical value. An application was made by the Danish Defence Research Board to the European Research Office, and in December 1963 the Committee had a visit from Col. Beaudry of ERO for the first personal discussion at DDRB's office.

Our Committee, which had been enlarged by addition of two leading officers from DDRB, had a decisive meeting at our Climatological Office on 20. April 1964. Here is was agreed to begin the project immediately by sending the first clonal plants up to Southern Greenland the following day, in accordance with a programme discussed with ERO. Subsequently a contract was written with ERO, the present writer being the Principal Investigator.

The phenological experience gained in the homeland was, of course, useful for the planning of similar research in Greenland for the purposes already mentioned: ecological analysis of the climate and its short-range changes.

In Jutland, W. Denmark, a special project (without direct connection to phenology) had been developed for the benefit of nondomesticated animals. This project had been underway for some years by the Arboretum in collaboration with climatologists, also for studying the influence of the plantings on climatic factors.

The Contract

With funds from the ERO contract it was planned to establish 6 pheno-climatological stations, together with protective plantings and fences, instructions and inspection and also to provide for transportation, potting, planting out and renewal of the selected clone-plants. However, all meteorological equipment, observations and other tasks were funded by the Danish Meteorological Institute. All other works with planning and the direct costs of labour were paid by the Danish institutions, involved in the project, particulary the Arboretum at Hoersholm and the Agricultural Experimental Station at Upernaviarssuk, Greenland.

Originally these planned stations cost about 32.000 Dan. kr. (4.500 U.S.Dollars). Later on, summer 1966, the project (without change to Contract) was extended to 10 pheno-climatological stations. The expenses for the last 4 were about 11.000 Dan. kr. (1.600 U.S. Dollars) only, some of them being partly equipped with meteorological instruments beforehand (tables below).

Just after the executive meeting of the Danish Committee the first portion af Clonal-plants was shipped to Greenland (21. April 1964) to the Agricultural Station at Upernaviarssuk, near Julianehåb and not far from the airport at Narssarssuaq, in care of Mr. Poul Bjerge for planting and tending.

The Committee now embraced The Royal Veterinary and Agricultural University with its Aboretum: Dr. C. Syrach-Larsen and Mr. P. Chr. Nielsen, the providers of plants, and its late professor of Genetics: C.A. Jørgensen (a prominent member of the Agricultural Committee for Greenland), further the Danish Meteorological Institute with its director Karl Andersen and the present writer, and finally the Danish Defence Research Board, represented by Col. Mouritzen and Major, now Lt.-Col. Winther.

Our committee had discussed the choice of plants, and it was agreed to select:

1) Greenland Willow (D: Steffens pil, L: salix glauca), recently brought from the Grønnedal/Ivigtut region to Denmark and reproduced at the Arboretum before the "re-export" to Greenland;
next:
2) AlpineCurrant (D: fjeldribs, L: ribes alpinum, the Rudolf Schmidt-clone);
and later:
3) some few Monkshoods (D: stormhat, venusvogn, L: aconitum sp.), already present at Upernaviarssuk;
and finally:
4) a dozen seedlings (i.e. not clones) of Siberian Larch (D: sibirisk lærk, L: larix sibirica).

Development of the phenological project

The originally planned 6 together with the supplementary 4 new phenological stations in Southern Greenland were built up in 4 chains I-IV, each of them containing one oceanic or atlantic = a, and 1-2 continental = b-c (b semi-atlantic, c most continental) stations, viz. - beginning from North West (cf. map. attached):

I a: Arsuk . village with trading station on small island; 393 inhabitants (1968).

I b: Grønnedal . naval station, started 1942 by the U.S. Navy, taken over by the Danish Navy 1951.

II a: Qagssimiut . village with trading station; 188 inhabitants.

II b: Narssaq Point . telegraph station, situated at the windy cape, not far from the township of Narssaq; 1758 inhabitants.

II c: Narssarssuaq . started as a U.S. military air field: Bluie West One, now Danish civil air field, ice reconnaissance, ionospheric, geomagnetic and satellite observing station(close by the old Norse settlement Brattahlid).

III a: Julianehåb . the oldest and now third largest township in Greenland; 2538 inhabitants.

n III b: Upernaviarssuk . State experimental station for sheeping, farming and agriculture. Manager: Mr. L.A. Jensen, associate Mr. Poul Bjerge; 17 inhabitants.

III c: Igaliko . village with trading station; 177 inhabitants. Some cultivable fields (near to the old Norse episcopal residence at Gardar).

IV a: Nanortalik . township on small rocky island; 1269 inhabitants.

IV b: Saputit . sheep farm, owned by Mr. Egon Jensen.

The 4 new stations adopted in 1965, marked by n to the left in the table above, constitute chain II (3 stations: a, b, c) and a valuable supplement III b to chain III. - The meteorological equipment of these 10 pheno-climatological stations appears in the table below:

Name of station	o/c	Thy	Hyg	set 4 T	set 2 Rm	An	Tg	SSR	sum
Arsuk	o	1	1	1	1	.	.	.	4
Grønnedal	c	1	1	1	1	1	1	1	7
Qagssimiut	o	1	.	.	.	.	.	.	1
Narssaq	c	1	1	1	1	.	.	1	5
Narssarssuaq	c	1	1	1	1	.	.	1	5
Julianehaab	o	1	1	1	1	1	1	.	6
Upernaviarssuk	o	1	.	1	1	.	.	.	3
Igaliko	c	1	.	.	.	.	.	.	1
Nanortalik	o	1	1	1	1	1	1	1	7
Saputit	c	1	.	1	1	.	.	.	3
		10	6	8	8	3	3	4	=42

This table indicates the number of different instruments, already sent to Greenland (compare the table page 19). The signification of the abbreviations is:

o = oceanic, c = continental
Thy = Stevenson thermometer screen
Hyg = Hygrometer
set 4 T = 4 thermometres: dry bulb, wet bulb, max., min.
set 2 Rm = a complete set of 2 rain-gauges
An = Anemometer
Tg = Thermograph (recording)
SSR = Sunshine recorder (Campbell-Stokes).

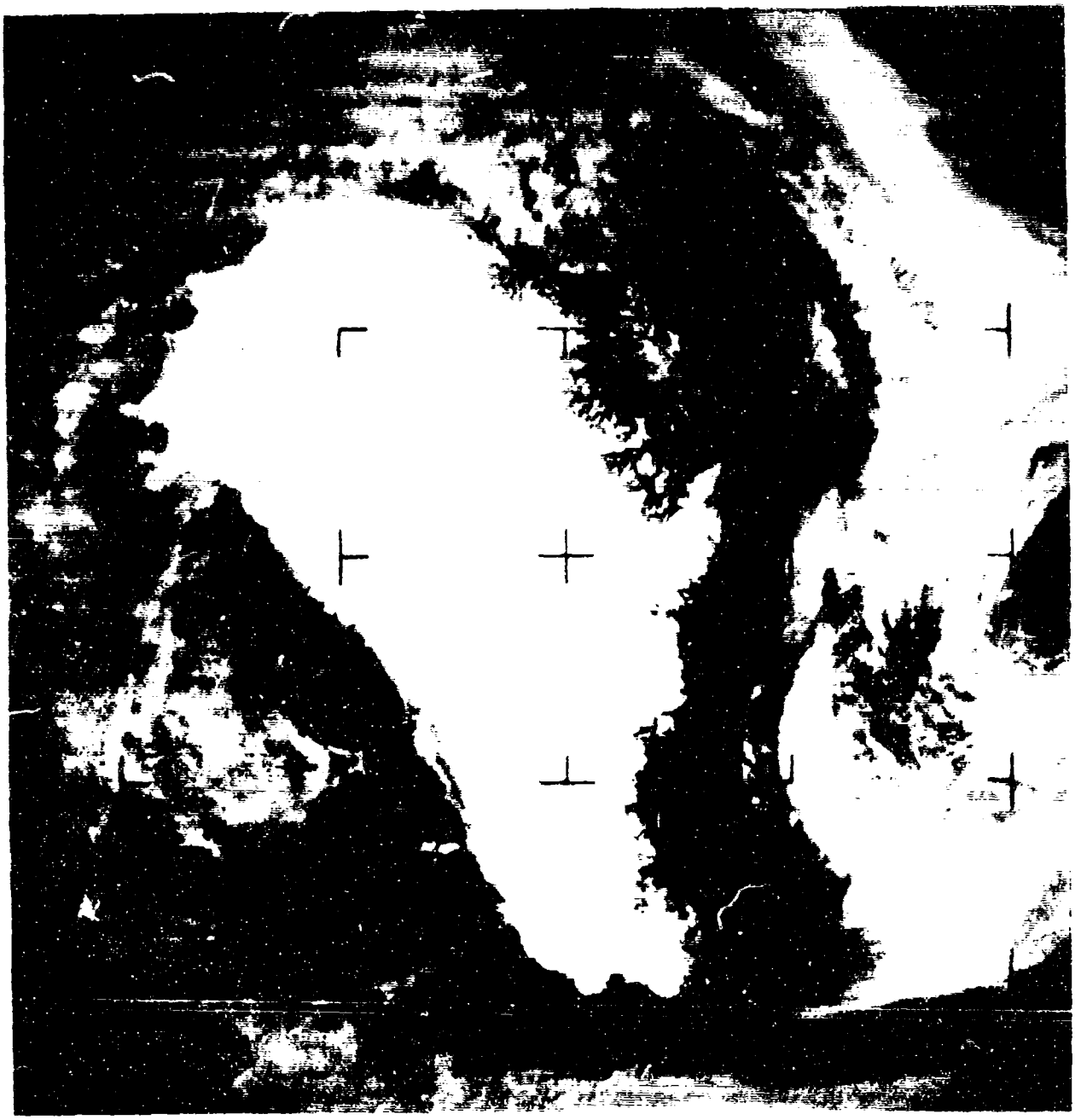
Climatic hardship in Southern Greenland

As phenological observers the same people were appointed that already were occupied with meteorological observations, and these are generally taken 3-8 times daily, as a sideline. They are able people, interested in this new field of research, but of very different education and employment. It was considered important that the enclosures with phenological plants, on the whole might be arranged in the immediate neighborhood of the dwellinghouses along with the meteorological equipment - the more as even in Southern Greenland blizzards are frequent, with snow often in great quantities and, below the freezing point, left in big waves of windblown snow-drifts.

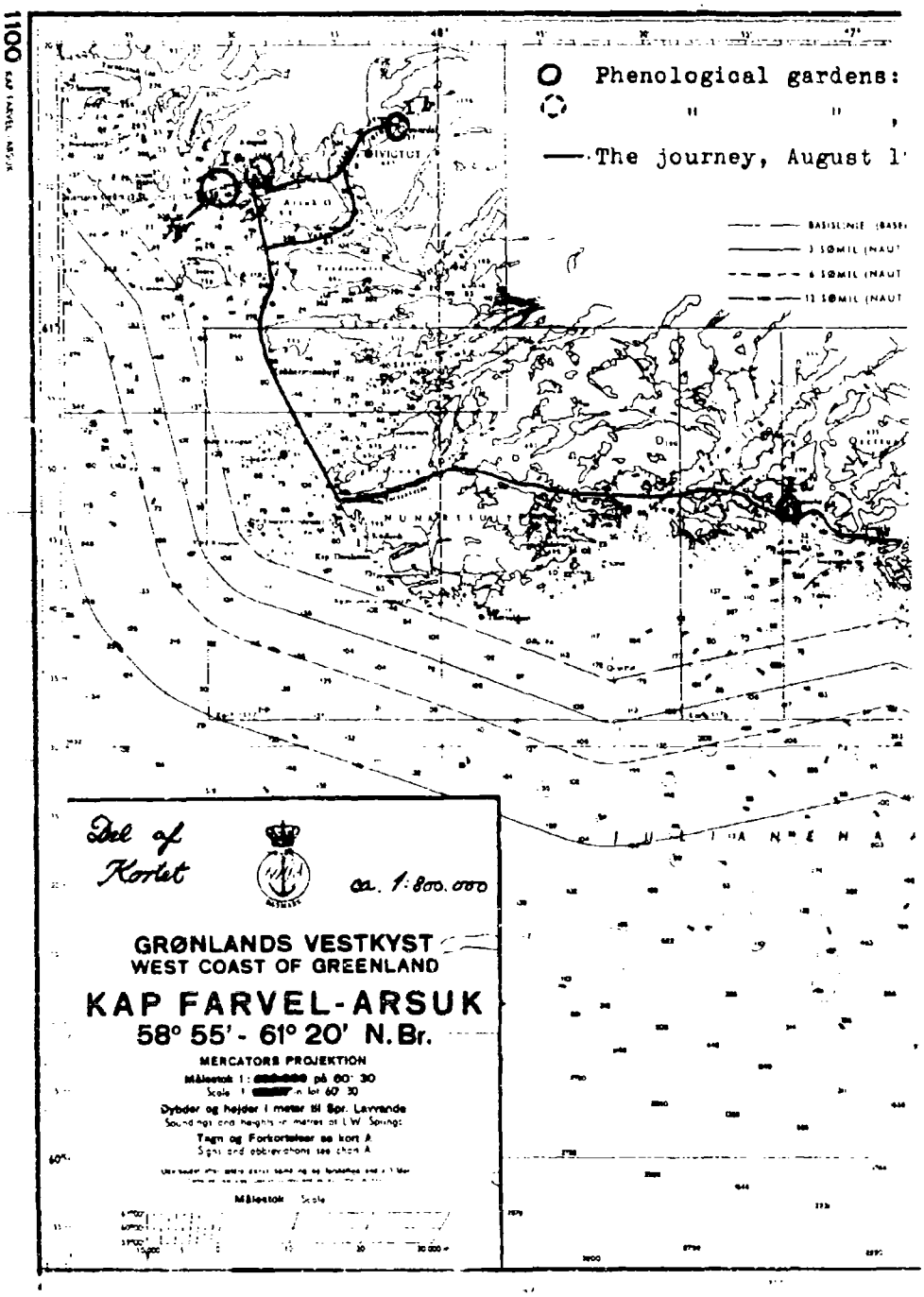
During the following two years (summer 1964 - summer 1966) more plants of the clones mentioned were sent from the Arboretum at Hoersholm to Upernaviarssuk, and - considering the hardship of climate and soil - they generally thrived well at Upernaviarssuk. Yet it may be added, that the almost snowless winter 1965-66 and the following very dry spring had been disastrous for the plants at Upernaviarssuk, not least the evergreen species of spruce, pine and fir. Many plants of these species, growing well since 1953, perished through those unfavourable climatic conditions; even a specimen of Norway Spruce, sown in 1892 near Narssarssuaq alive up to this time, died away.

The more fortunate was it, that in this case neither the natural tree growth, consisting of shrubby willow and birch, nor the planted Siberian Larch, seemed to have been hurt. The latter had been planted at a rather great extent during primary experiments with tree plantings during the last 15 years.

A paradox in the sense of the expression a "hard winter" emerges from the fact, that the following winter (1966-67), due to just mild thawing periods, followed by re-freezing of snow, partly covering herbs and grass, caused the death of many thousands of sheep - at a rough estimate 28.000 ewes (out of 48.000) starved in the Julianehåb district; but as to the plants, this winter was rather gen. al.

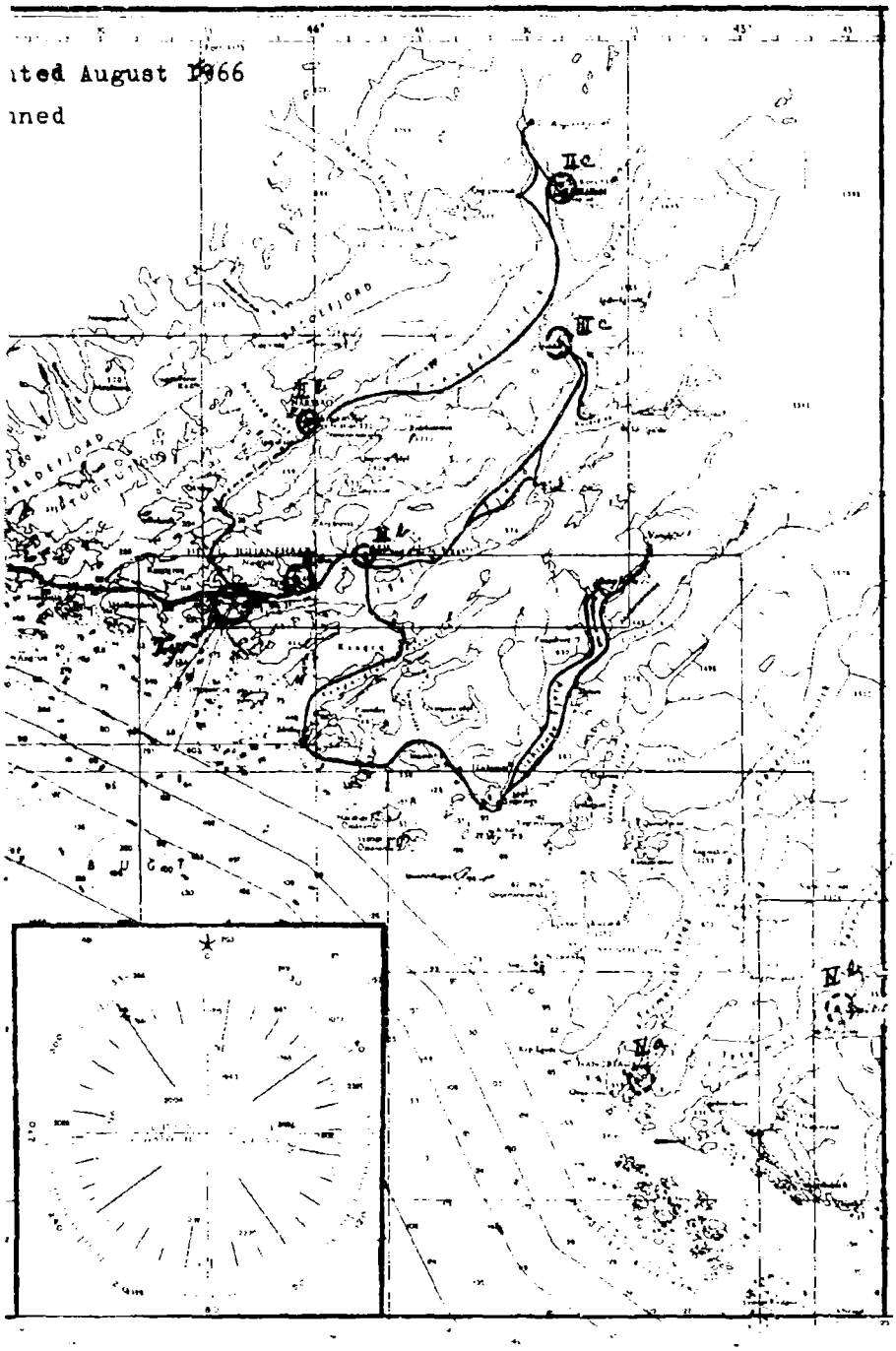


Satellite photo, taken by ESSA 2 from 1400 km altitude, [illegible]
1966 - just during the first plantings of phenological [illegible]
ing Greenland and the surrounding waters, partly covered by [illegible]
partly veiled by clouds, yet with vast, dark areas near [illegible]
hardly any ice nor clouds. Right below: a cloud system [illegible].
(Recorded at Narssarssuaq as day-light picture).


Phenological gardens:
The journey, August 1
Del af Kortet
ca. 1:800.000
GRØNLANDS VESTKYST
WEST COAST OF GREENLAND
KAP FARVEL-ARSUK
58° 55' - 61° 20' N.Br.
MERCATORS PROJEKTION
Dybder og højder i meter til Spr. Lavvande
Tegn og Forkortelser se kort A
Målestok Scale

ıted August 1966

ıned



The newly planted phenological garden at Narssarssuaq. (P.Chr.Nielsen phot. August 1966).

Narssarssuaq airfield, looking east. (J.S. Fabricius phot. May 1967).

Cutter in polar drift-ice in the Julianehåb Bay, 17th June 1970. multi-year ice covering 80 % of the waters. In 1968-69-70 the drift-ice was unusually ample and compact (J.S. Fabricius phot.).

In the spring of 1966 the Greenland willows and Alpine currants sent up two years before, thrived rather well, mostly in the nursery at Upernaviarssuk, but partly planted out at Nanortalik and Saputit (IV a-b above), too. About 40 plants of the selected Steffen's willow clone, and further 190 seedlings of Siberian Larch, that winters so well, were planted in pots at Upernaviarssuk, the larches serving as protecting nurse trees for the clone-plants in the coming phenological gardens.

At the Agricultural Station a considerable number of Monkshoods (Aconitum sp.) were available. Growing as cultivated clonal plants, they were considered apt for the purpose, and of especial interest too, as their flowering is as late as in August, which means a valuable seasonal spreading out in the observing programme.

Accomplishment of the phenological gardens

Thus it was now due time for planting out of the 4 species of clone-plants and nursery-larches at the 10 stations. Starting the contact with the Royal Greenland Trading Company in June 1966, the contractor and committee got an answer (d: 13/6), favourable to our inquiry about airline-tickets and transportation facilities among the widespread research stations. Thus Mr. P. Chr. Nielsen and his associate could leave for Greenland (26/7) by airplane, and a few days after the arrival at Upernaviarssuk, the planting trip was started. It took place in a cutter belonging to the Agricultural Station.

Together with Mr. Nielsen and his associate were Mr. Poul Bjerge, who is in charge of the experiments with planting and cultivation of vegetables and ornamental plants, and Mr. O.K. Vestergaard, the veterinary surgeon, who had arranged his inspection trip in the district so that the planting of some phenological gardens could be carried out in connection with the voyage.

This arrangement was made possible according to the kind goodwill of Mr. Louis A. Jensen, manager of the Station, and for the

benefit of our plans, Mr. Vestergaard acquiesced in making some detours, so that not only the sheep-farms in the large Julianehaab district were inspected as usual before the great butcherings in August, September and October, but also the 8 (out of the 10) phenoclimatological stations, for thorough instruction and achieving the planting-out project. - Only the two stations Nanortalik and Saputit (IV a-b) were left to the care of Mr. Poul Bjerge later on in the autumn.

The boat-trip started with Narssarssuaq and Narssaq Point (1/8-3/8), and via Julianehaab came Igaliko-Qanisartut (5/8-6/8). After some days, occupied with veterinary purposes &c followed Julianehaab itself (12/8), later on Qagssimiut, Grønnedal, Ivigtut and Arsuk (15/8-19/8), the stations farthest in NW. Upernaviarssuk had been visited 2-3 times for planting and providing during the trip, now again (20/8-21/8) before the return to Julianehaab (22/8), then by ship from here to the airport of Narssarssuaq (22/8) and finally (24/8) homewards to Copenhagen by air.

A good deal of the sojourn in Greenland was spent on travels; it had been possible, however, to establish 8 of the 10 phenological gardens and to give instructions about the purpose and details of the scheme &c to the people foreseen ready to look after the plants.

Due to his experience and knowledge about conditions in Greenland and its population Mr. Poul Bjerge was an extremely useful partner; he even acted as an interpreter, when necessary, between assistance with the manual work. The purpose of this was, at all the stations to patch up penfolds; these are built up of wooden rods and poles, up to 1½-2 metres above the ground, so as to be considered as "hare and sheep-tight" for the protection of the gardens to be planted inside.

This task consisted on the whole of planting out, inside the fences, of

1) 1 bigger and 4 smaller plants of the Greenland Willow (Steffens pil) - origin at the Marine station at Grønnedal (Ib);
2) 2 Monkshoods (stormhat or venusvogn in Danish), a perennial from Upernaviarssuk as mentioned;

3) 3 Alpine currants, clone Rudolf Schmidt.

Inside each of the fences were also planted 10 Siberian Larches, merely as protecting nurse trees, not observational plants.

Care was taken, that the plants were not too close to each other; yet the area of these phenological gardens did not exceed 80 m^2 as at Narssarssuaq, where it was impossible to find a planting place close to the meteorological station. The distance from the dwelling-house and meteorological station was else in most cases insignificant (25-75 m); only at Qagssimiut, where two different gardens were founded, one of them was at a distance of 300 m.

At Qagssimiut and Narssaq Point the climatic conditions, particulary the frequent foehn winds, will make the development of the plants questionable.

Present state of the project

After the achievement of the task, mentioned above, followed Mr. Poul Bjerge's boat-trip for inspection, instruction and final plantings at the remaining two stations:

Nanortalik and Saputit (IV a-b). We have regularly got information from the 10 stations by Mr. Bjerge as replies to inquiries sent up, not only in Danish, but in Greenlandic language as well.

The last reports (at hand: November 1969 - March 1970) give an interesting survey and a very useful guidance for the procedures and the planned travels of inspection in the coming summer of 1971.

On the whole the Greenland Willow seems to thrive best and to be most apt for the purpose. Usually Monkshood also seems to resist and survive; but on the other hand, Alpine Currant has in some few cases only been able to stand the hardship of climate and soil, a deplorable fact, that may lead to the abandonment of this plant and replacing it by another - an item for discussion at and with the Arboretum.

Some details from the phenological gardens are given below, viz:

I. Arsuk: alive are 1 willow, 2 monkshoods and 1 Siberian Larch; foliation (leafing) of willow: 8/6.
Grønnedal: all plants alive (1969).

II. Qagssimiut: 3 willows and 1 monkshood alive (1969).
Narssaq Point: only the willows alive; leafing: 1/6.
Narssarssuaq: all the plants seem to thrive, but in the beginning of September the flowers of monkshood hurt by frost; leafing of willow: 13/5, of Alpine currant: 7/6.

III. Julianehab: the plants were spoilt by building works in the neighborhood; a new garden is being established.
Upernaviarssuk: 2 willows (15/5), 1 Alpine currant and the monkshoods alive.
Igaliko: no plants alive; meteorological station damaged by violent storm.

IV. Nanortalik: only willows alive.
Saputit: all plants alive (1969); leafing 25/5.

We thought it appropriate to defer the second voyage of inspection and renewal (and the last before Contractor's duties are officially taken over by the Danish Meteorological Institute) until sufficient experience were gained and especially the power of resistance and survival of the plants chosen could be estimated. It is evident from the survey above, that the summer of 1970 may be due time for the purpose.

It is considered probable, that the clonal plants, turning out to be hardy and resistant in our project, will gradually become reliable "living climatic witnesses", when they have come through the first, always most critical years.

Environmental conditions

In order to arrive to some conclusions a few relevant climatic data are studied in comparison with the phenological data from the summer of 1969 (tables 1-2), the first available after the planting,

considered apt for the purpose. Unfortunately this summer of 1969 was unusual cool and changeable in Southern Greenland.

The region concerned covers an area from Nanortalik up to Arsuk (vide:map), a distance about 250 km (or 135 naut. miles). The whole ice-free land area (i.e. not covered by perennial ice and snow) is hardly 1 % of the total area of the World's greatest island (2.182.000 sq. km, and about 6 % only of the whole ice-free area - 380.000 sq. km).

The annual mean temperature is (table 1) rather uniform along the coast and inland along the fjords as well: about 1-2°C in recent years; in the 19. century and beginning of the present, however, the corresponding temperatures were nearly 0°C, i.e. 1-2°C lower. But the changeability during the single months and even between whole years is considerable, notwithstanding the nearness of the Atlantic Ocean.

This is, for the whole region, due primarily to the great differences of weather and especially temperature with cool continental NW. and NE. winds changing with milder winds from the South, especially the mild, often foehn-carrying SE. wind. Thus weather, on the whole, is divided between two different climatic types with average conditions much less frequent than according to the Gaussian law of distribution.

This, of course, means a further hardship for the fauna and flora, although the contrasts are not unfrequently mitigated by the passing barometric Lows (i.e. depressions), coming from the Atlantic and travelling along the W or E coast of Greenland, the former giving most warmth to Southern Greenland. Barometric Highs are rare in the coastal region, a great stable and effective anticyclone usually being settled over the inland glacier.

As the monthly mean temperatures rarely exceed 10-11°C, even in warmest month of July and only in the innerest fjord-landcapes (cf. table 1), the climate and vegetation types may on the whole be considered as artic.

The annual range of temperatures inland is about twice that at the coastal skerries, and this means a lot for the phenological development, the lower minimum temperatures being of less vital inportance. - It is

an interesting feature, that the first Norse/Icelandic colonists nearly a thousand years ago (since 983) were aware of these circumstances and among all regions available chose the inner fjord-landscapes of Julianehaab (60°43'N) in the South and of Godthaab (64°10'N) at the West coast for their two settlements, districts even today considered as the most climatically "temperate" of all Greenland.

Of two special climatic traits, characteristic of Southern Greenland, the foehn has already been mentioned. It remains only to be added, that this typical warm and dry wind (also known from the Alps and as the Chinook in the W. USA) is most frequent during winter and spring, is very variable in extension, duration and violence, but - through melting or rather sublimation of snow and ice - may be an important advantage (when even temporary only) for the grazing animals as sheep; for the plants, however, it means a still greater hardship as a consequence of the inevitable relapse later.

The other factor, influencing the climate and general conditions of life in whole Southern Greenland is the great maritime coastal stream with drifting polar ice. With a width of about 50 km (30 naut. miles), more or less crowded with patches or floes of pack-ice (up to thickness about 10 m), this maritime flow of ice, originating from the Eastern Area of the Arctic Ocean, is loosened and carried away in the straits between NE-Greenland, Spitzbergen and Jan Mayen during the relatively mild summer and covers about 2000 km southward (nearly 1100 naut. miles), moving at a speed of about 1/4 knot (½ km/h), rounding Cape Farewell about half a year later, during average midwinter (end of January); yet this date is very changeable. Within a week it will pass the island of Nanortalik (the SE. outpost in the present project), and mostly within a month later Arsuk at the opposite (NW.) end is passed.

During the whole summer and autumn the coast, bays and outer parts of the fjords are crowded with this polar pack-ice and with tall ice-bergs, arising from the summer-warmed Greenland Glacier,

dispersed between the floes. This, of course, affects the climate of the region immensely, above all at the coast, but, particularly as a result of the sea-wind moving inland, along the fjords, too. Here usually outflowing breezes prevail, not much cooled by the neighbouring glacier-arms. Therefore an advective change of wind direction entails a considerable change of temperature and weather (as from sunshine to clouds, fog or precipitation), especially in years with excess of crushing pack-ice, as it was experienced just in the past summer of 1969.

When passing South-South-West the cold East Greenland Stream keeps close to the shore, partly due to the general deviation at right, partly to the milder Irminger Stream, a left sidebranch of the Gulf Stream, encountered in the Denmark Strait, off Iceland, latitude about 66°N. By and by the main stream intermingles with the milder water, so that the Godthåab district at the W. coast is not always reached by the ice during the following summer, and then, if it is the case, with a decreased effect only. But the Julianehaab district is not spared; the progressing melting and loosing up of the ice floes may even, with favourably conveying sea-winds (from SE to S), facilitate its penetration into the bays and fjords. -

This brief explanation of the climatic particularities of Southern Greenland with its intrinsic paradoxes and irregularities may serve as guidance in the survey of the climate and of the first phenological data given in the tables (1-2). Here especially the thermal data are dealt with, because other climatic factors, in the first instance, may be treated indirectly as to their effects upon temperature:

Survey on climate and environment, South Greenland

growth and thriv. of plants	promoted by high temperature and great thermal amplitudes	i.e. great values = continental	conditioning climatic factors: sunshine, dryness; calm
		i.e. small values = oceanic	conditioning climatic factors: precipitation, humidity, fog clouds; wind; drifting ice

Conclusions

The key to understanding this connection is, that precipitation and humidity in Southern Greenland, on the whole, suffices for the thriving of plants (table 1). Yet the precipitation is more ample than in the Danish homeland. Further the phenological data show that the higher inland temperature is more favorable, although the humidity is lower than at the coast (table 2).

It is evident that the low coastal temperatures e.g. at Arsuk has had a retarding effect on the foliation (8/6 = day 159.) of the willow, compared even with the windy station at Narssaq (1/6 = day 152.): 7 days, but much more compared with Upernaviarssuk (15/5 = day 135.) and the summermild Narssarssuaq (13/5 = 133.): not less than 24 and 26 days respectively. On the whole, foliation of the Greenland willow seems to take place quickly during a mild spell with a mean temperature about and above 6°C and the daily maxima exceeding 12-13°C.

The difference of foliation up to 19 days between Narssaq and Narssarssuaq is quite compatible with this, the early date at Upernaviarssuk partly too; yet is remains to be explained that two days only separate this station from the milder Narssarssuaq. It may be, however, that stricter definitions of the foliation will be needed.

When comparing the leafing-out of the willow in the phenological gardens, it is necessary to remember that the plants are not fully established so far and that some of them may be delayed in their leafing-out as a consequence of this fact. Thus it is still too early to draw any final conclusions about the influence of climate on the plants in the phenological gardens in Southern Greenland.

Yet data from 1969 may induce the conclusion, that a change of 1°C in mean spring temperature entails a change, i.e. a promoting or retarding effect, of about 12 days in Southern Greenland, at least with climatic and environmental conditions as those prevailing in the cool and changeable spring and summer of 1969.

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Note. At left the language is indicated (Danish, English/American, French, German).

For further references: vide Köppen & Geiger, Putnins and Vibe (above).

Mean Monthly Temperatures and other climatic data

(1961-68 interpolated and smoothed).

TABLE 1

	J	F	M	A	M	J	J	A	S	O	N	D	Y
	mTt: mean monthly temperature												
Ivigtut Grønnedal	-5.9	-5.6	-3.0	1.5	6.0	9.5	11.4	10.1	6.5	2.6	-1.4	-4.4	2.3
Julianehåb	-6.7	-6.2	-3.2	0.9	5.4	7.7	8.9	8.9	6.3	2.5	-2.0	-5.0	1.5
Narssarssuaq	-6.8	-6.0	-2.5	0.0	6.2	9.8	11.4	9.8	5.6	1.5	-1.5	-4.0	2.0
Igaliko	-7.0	-6.5	-2.5	0.8	6.3	9.2	11.6	9.7	6.0	1.6	-1.2	-3.2	2.1
Nanortalik	-2.6	-2.5	0.0	1.3	3.9	4.9	6.6	7.1	5.4	2.3	0.0	-1.5	2.1
	mRR: mean monthly precipitation and humidity (%)												
Ivigtut Grønnedal	84	66	85	64	89	81	78	96	147	144	118	81	1128mm
%	58	54	55	56	60	61	58	62	62	58	56	55	58
Julianehåb %	58	58	58	60	61	68	66	67	64	61	59	59	62
Nanortalik	60	66	40	57	45	73	70	91	112	122	75	51	862mm
%	67	65	66	64	66	68	65	66	67	63	63	63	65

Annual precipitation (mm): Godthåb 600, Narssarssuaq 755, Igaliko 841.

Explanations to Table 2:

nTn = lowest minimum; mTt = mean temp.; mTx = mean maximum; xTx = highest maximum. I, II, III = first, second and third decade; M = whole month with date for foliation of Greenland willow; foliation = means ; of Greenland willow.

Decade temperatures for 8 stations in the region of Southern Greenland: April - May - June 1969.

TABLE 2

			APRIL				MAY				JUNE			
			nTn	mTt	mTx	xTx	nTn	mTt	mTx	xTx	nTn	mTt	mTx	xTx
Ia	Ar-suk	I				2.0				12.0				14.0
		II				6.0				8.0				10.0
		III				10.5				13.5				11.0
	foliation/M			-1.5				2.0			8/6 = 5.0		(day 159.)	
Ib	Grøn-nedal	I	-13.0	-5.7	-2.7	3.6	-2.1	3.2	6.9	13.2	-0.6	7.5	12.1	15.2
		II	-12.0	-2.0	1.7	5.4	-3.2	3.9	7.4	9.0	0.2	5.5	9.4	11.2
		III	- 3.4	3.1	6.6	15.0	-6.5	3.6	8.4	13.4	2.1	6.3	9.2	11.2
	foliation/M			-1.5				3.8				6.4		
IIb	Nar-ssaq	I	-12.0	-4.8	-1.8	2.0	-1.6	4.1	7.5	10.7	-0.5	7.7	12.3	16.5
		II	- 9.2	-1.8	0.8	4.5	-2.0	3.8	6.4	8.5	-1.5	5.4	8.7	11.0
		III	- 3.0	3.1	6.2	9.8	-4.2	3.3	7.2	13.5	2.5	6.1	8.8	11.0
	foliation/M			-1.2				3.7			1/6 = 6.4		(day 152.)	
IIc	Narssar-ssuaq	I	-15.4	-5.6	-2.2	2.7	-1.0	6.5	10.8	14.4	3.4	10.3	14.3	18.7
		II	-11.0	-0.3	4.1	7.8	-2.8	5.6	8.9	12.0	2.0	7.3	10.9	15.5
		iII	- 2.0	4.8	7.9	12.8	-3.5	7.4	12.4	18.6	4.0	8.6	11.3	13.8
	foliation/M			-0.4			13/5 = 6.5		(day 133.)			8.7		

TABLE 2 (continued)

			APRIL				MAY				JUNE			
			nTn	mTt	mTx	xTx	nTn	mTt	mTx	xTx	nTn	mTt	mTx	xTx
IIIa	Julianehåb	I	-14.9	-6.0	-2.2	1.0	-5.4	4.5	8.5	13.5	-1.6	6.8	11.4	16.2
		II	-10.6	-1.0	3.1	7.3	-3.5	3.8	7.4	10.2	-2.0	4.5	8.1	10.4
		III	- 3.7	3.4	6.6	12.2	-4.4	3.7	8.5	16.0	0.4	5.3	8.3	11.5
	(nil)	M		-1.2				4.0				5.5		
IIIb	Upernavi-arssuk	I	-13.2	-5.4	-2.8	3.5	-3.6	4.2	7.7	12.3	-0.7	6.7	11.2	16.8
		II	- 9.3	-1.0	3.0	5.3	-2.6	3.5	7.0	10.7	-1.8	3.9	6.8	8.7
		III	- 3.2	3.5	6.0	11.3	-4.7	3.1	7.2	14.1	0.6	5.1	7.9	11.2
	foliation/M			-1.0			15/5 = 3.6		(day 135.)			5.2		
IVa	Nanor-talik	I	-13.0	-4.2	-1.2	2.6	-2.5	5.0	8.1	12.5	-2.0	5.4	9.3	13.5
		II	- 7.0	-0.6	1.9	5.6	-2.0	3.6	6.6	8.5	-3.0	4.1	7.7	10.0
		III	- 6.5	3.4	6.8	10.0	-3.0	4.0	8.0	14.0	0.5	4.9	8.4	10.5
	(nil)	M		-0.5				4.2				4.8		
IVb	Saputit	I	-17.2	-5.3	-0.9	2.4	-2.3	6.1	10.0	12.5	-0.5	8.0	12.9	17.9
		II	-14.2	-1.0	4.1	8.5	-2.1	5.5	9.0	12.6	-0.9	5.2	10.3	13.2
		III	- 3.3	3.9	7.3	9.7	-4.7	4.7	10.8	18.1	1.7	6.9	10.3	12.7
	foliation/M			-0.8			25/5 = 5.4		(day 145.)			6.7		

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13. ABSTRACT

This is a study in phenology. It has been carried out under the cooperative auspices of the Danish Government and the U.S. Army's European Research Office. In this, study was made of the correlation between the life cycles of certain Arctic plants, especially planted in S.W. Greenland, and the prevailing meteorological and climatic factors and conditions obtaining there. The objective was to determine to what extent such conditions may be ultimately predicted from observations of plant growth alone. Although the period of years spanned (1964-1970) is too short to draw firm conclusions, tentative correlations are drawn and set forth in the report.

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